

Metals in Lung Tissue from Autopsy Cases in Mexico City Residents: Comparison of Cases from the 1950s and the 1980s

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In autopsies performed on residents of Mexico City during the 1950s and 1980s (45 males and 24 females and 42 males and 42 females, respectively), concentrations of cadmium, copper, cobalt, nickel, and lead in the lungs were studied by atomic absorption spectrometry. Sharp increases were noted in samples taken in the 1980s compared to those from the 1950s. In samples from both time periods, the concentrations were influenced by gender. Smoking was not associated with higher levels of the metals. Only lead seemed to have a relation with age. The enormous differences by gender in the 1950s could be due to different patterns of exposure. The differences among samples from both periods appear to be associated with the increase of air pollutants in the metropolitan areas of Mexico City during the years under study. These results reinforce the importance of studying lung tissue to monitor air pollution by metals. *Key words:* atomic absorption spectrometry, cadmium, cobalt, copper, heavy metals pollution, lead, lung, nickel. *Environ Health Perspect* 104:630–632 (1996)

During the past 30 years, major Mexican cities and, in particular, the vast metropolitan area of Mexico City, have experienced drastic changes (1). Industry has boomed, urban population has more than doubled, and a dramatic increase in motor vehicles has brought on almost unmanageable congestion on streets and highways. Reports in 1972 indicated that the total number of motor vehicles in the entire country was 2.5 million, and in Mexico City alone 1 million were circulating. Today in Mexico City, there are almost 3 million vehicles (1,2). These and various other factors have produced a high concentration of air pollutants. Reports on air quality began in 1976, but they were produced at irregular intervals. Since 1986, SEDUE (Secretaría de Desarrollo Urbano y Ecología) has conducted monitoring programs of air quality in a more accurate and comprehensive way, and the only reported metal now or before 1986 is lead (2). During 1986 and 1987, SEDUE reported 3-month average concentrations of lead in air as high as 14 mg/m³ in heavily industrialized areas of Mexico City (1,3).

In the affected areas, pollution control regulations have not been adequately enforced. This and other inadequacies in management have resulted in grave consequences. Investigations of the trend of toxic metal concentrations in lung tissue are of primary interest in research projects and in studies concerning health protection. Research in human exposure to the pollutants often uses tissue samples from repositories in pathology laboratories (4). We analyzed concentrations of metals in lung samples, currently preserved in a pathology laboratory in Mexico City, derived from

autopsies performed during the 1950s and the 1980s.

Materials and Methods

We compared levels of cadmium, copper, cobalt, nickel, and lead in consecutive lung samples (69 taken during the 1950s and 84 from 1980s) at the Instituto Nacional de Cardiología in its Department of Pathology. The fixative was the same for all samples. Individual characteristics, such as age, gender, and place of residence, that could potentially be related to exposure to airborne pollutants were examined. However, data on cigarette smoking and the smokers' occupations were incomplete in the clinical records. Smoking was included when it was mentioned in the clinical records. All the cases had a medium to medium-high socioeconomic status. Cases of pregnancies or pulmonary lesions, other than light edema, which did not distort the lung morphology, were excluded. All the samples were dissected with the same knife and treated with the same formaldehyde solution. The same flasks with the same caps were used. Samples were taken from lungs previously sliced, but the samples did not include major bronchi or certain other types of tissue. Information concerning specific anatomical sites was lacking. In the 1980s all the lungs were perfused with the fixative before they were sliced. This procedure had not been used in the 1950s. Samples were treated according to a modification of a technique described by Locke (5): 0.5-g lung segments fixed in formaldehyde were dried at 150°C for 20 min to evaporate the formaldehyde. Dried samples were placed inside quartz beakers which had been

washed with 1:1 nitric acid and sulfuric acid solutions (6).

Samples were digested with 2 ml of a mixture of pure nitric and sulfuric acids and heated for 20 min at 150°C. Beakers were capped and enclosed samples were boiled until a small volume was obtained. Digested samples were filtered and diluted with distilled, deionized water to 25-ml volume. The same water was used for the blanks (7,8). Samples were analyzed by atomic absorption spectrometry (model 2380, Perkin Elmer, Foster City, California). The light source came from a hollow cathode lamp, specific for each separate element, using an acetylene-air flame. Each metal was identified after subtracting the results obtained. Formaldehyde and the blanks were also analyzed to exclude metals from this source. Accuracy was assured by three random determinations of seven different standard solutions, prepared with the same reagents used during the analysis. Wavelength, detection limit, sensitivity, slit and linear interval are summarized in Table 1. Each sample was analyzed in triplicate. Results were defined as microgram per gram of dry lung tissue (9,10).

To assure external quality controls, we analyzed 10 samples from each set of lung tissues by inductively coupled plasma emission spectrometry (11). In all the cases the differences within the samples was less than 15%. The averages for concentrations of the metals are summarized in Tables 2 and 3. A multiple regression analysis (Statgraphics, version 5.0) was performed to identify the association between the variables (gender, smoking habit, decade, and age) and metal concentrations in lung tissues (Table 4).

Results

Eighty-four samples from 85 cases (42 males and 42 females, ranging from 11 to 87 years of age) from the 1980s and 69 samples from the 1950s (45 males and 24

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Table 1. Analytic parameters for atomic absorption spectrometry

Element	Wavelength (nm)	Width (nm)	Linear interval (mg/l)	Detection limit (ppm)
Cadmium	228.2	0.7	2.0	0.1
Cobalt	240.7	0.2	3.5	0.08
Copper	324.8	0.7	5.0	0.06
Nickel	232.0	0.2	2.0	0.35
Lead	217.0	0.7	20.0	0.37

Table 2. Mean concentrations of metals in lung tissue from the 1980s and the 1950s

Element	Mean \pm SD (mg/g dry weight)	
	1980s (n = 84)	1950s (n = 69)
Cadmium	25.6 \pm 6.5	1.2 \pm 0.37
Cobalt	37.2 \pm 8.67	3 \pm 0.97
Copper	44.8 \pm 15.7	10 \pm 2.97
Nickel	57.6 \pm 9.3	3 \pm 0.96
Lead	134.3 \pm 26.7	12 \pm 4.97

Table 3. Mean concentration of metals by gender from the 1980s and the 1950s

Element	Mean \pm SD (mg/g dry weight)			
	Males		Females	
	1980s	1950s	1980s	1950s
Cadmium	23.3 \pm 5	1.19 \pm 0.3	27.8 \pm 6.9	10.08 \pm 1.3
Cobalt	38.1 \pm 5.7	4.03 \pm 0.9	36.4 \pm 10.7	2.04 \pm 0.02
Copper	32 \pm 8	9.02 \pm 2.5	57.4 \pm 10	10.08 \pm 2.3
Nickel	51.1 \pm 5	3.09 \pm 0.4	63.9 \pm 7.9	3.54 \pm 0.9
Lead	122.9 \pm 13	10.6 \pm 2.1	145.2 \pm 31.4	13.3 \pm 3.5

females, ages 7–79) were analyzed. All the 1980s samples were from consecutive autopsies; samples from the 1950s were from well-preserved cases. None of the cases had a history of lung diseases, and only one case from the 1980s was excluded because this individual was pregnant at the time of death. All samples were from individuals who had been permanent residents of Mexico City. The five metals analyzed in the fixative were below the detection limit in all samples. A high increment of metal concentrations in cases from the 1980s was observed compared to those from the 1950s (Table 2).

Differences by gender were evident in both time periods. Samples from the 1950s showed high levels of cadmium among women but not samples from the 1980s. This gender difference could be explained by different patterns of exposure, but not by smoking. Clinical records showed that none of the women from which the 1950s samples were taken smoked, and only three men were positive. On the other hand, in the 1980s, more women and men smoked, and this may explain why cadmium was not higher in women compared to men for these samples.

Samples from the 1980s showed increases in lead, copper, cadmium, and nickel among women compared to 1950s samples from women. Metal concentrations in the 1980s showed, with exception of cobalt, that the mean value of the other metals was slightly higher among women (Table 3).

There was no association between age and smoking and the concentrations of the metals (Table 4). Only lead seemed to be associated with age.

Discussion

Little information is available concerning lung lesions among individuals living at high altitudes exposed for an extended time to significant levels of pollutants (Mexico City's altitude is 7500 feet above sea level). Airborne pollutants enter the respiratory system via the extensive surface of the lungs (12). The toxic effects of the metals included in this research are of serious concern (13–17). The toxicity of lead on the central nervous system and on organs such as the

Table 4. Multiple regression analysis for metals in lungs: model fitting results for each metal

Metal	Variable	Coefficient	SE	t-value	Significance level
Cadmium	Constant	-56.35	4.78	-11.78	0.00
	Decade	0.02	0.002	12.10	0.00
	Gender	-0.46	0.043	-10.56	0.00
	Age	-0.00006	0.0011	-0.59	0.551
	Smoking	0.0272	0.0459	0.59	0.553
	Adjusted r^2	0.81			
Copper	Constant	-40.5	2.29	-17.7	0.00
	Decade	0.02	0.001	18.35	0.00
	Gender	-0.168	0.020	-8.08	0.00
	Age	0.0004	0.0005	0.77	0.44
	Smoking	-0.008	0.022	-0.37	0.70
	Adjusted r^2	0.88			
Cobalt	Constant	-70.89	3.057	-23.18	0.00
	Decade	0.036	0.001	23.40	0.00
	Gender	0.123	0.027	4.42	0.00
	Age	0.001	0.0007	1.58	0.11
	Smoking	-0.025	0.029	-0.86	0.38
	Adjusted r^2	0.9			
Nickel	Constant	-80.5	1.405	-57.2	0.00
	Decade	0.041	0.0007	58.04	0.00
	Gender	-0.071	0.0128	-5.58	0.00
	Age	0.0002	0.0003	0.80	0.424
	Smoking	-0.0053	0.013	-0.39	0.690
	Adjusted r^2	0.9			
Lead	Constant	-66.02	1.49	-44.19	0.00
	Decade	0.034	0.0007	45.27	0.00
	Gender	-0.076	0.013	-5.59	0.00
	Age	-0.0007	0.0003	-2.20	0.0286
	Smoking	0.0138	0.0143	0.96	0.33
	Adjusted r^2	0.9			

kidneys has been well documented. Few studies, however, have related metals to structural damage or impaired function of the lungs (16–22). Changes in immunological function by lead and cadmium have been reported in a few studies (23,24). Cadmium exposure has been associated with emphysema, and it may also induce pulmonary fibrosis (25). The carcinogenic effect of cadmium exposure is still controversial (26). Cadmium, nickel, cobalt, and lead are found in tobacco (27). It has been reported that Mexican tobacco has a high concentration of cadmium (28). In the respiratory tract, nickel is carcinogenic (29,30). Although there is no substantial evidence that copper is carcinogenic, lung cancer is frequent among copper workers. In tumors induced by hydrocarbons, the copper concentration in tissue is higher than normal (31,32). Cobalt

is usually present in human tissue. Its carcinogenic effect has been demonstrated experimentally. This effect is not as potent as that of nickel, but is higher than previous reports would indicate (13,33).

We found higher concentrations of metals in the lungs than previously reported. The fixative showed a concentration below the detection limit, similar to the concentration in water or other reactants used in the analysis of the samples. Thus, contamination from these sources can be ruled out (34). Metal concentrations differ according to the region of the lung (35–37) and, although it is assumed that more 1980s samples with higher levels of metals were included, the magnitude of differences noted between both periods of time under study cannot be explained solely by sampling bias. A possible explanation is the increase of air pollution

levels due to the increase of vehicles and the growing number of industries in Mexico City. This is supported by some studies that report that the concentration of lead, copper, and nickel in the air are from anthropogenic sources (39). In this study, smoking was not a factor in the increased concentrations of metals in the lung.

All of these factors, in addition to the limited information in the literature concerning metal concentrations in the lungs and smoking, are important in consideration of the total problem (27). The decreased deposition for cobalt and nickel during the 1950s could be a consequence of a lower exposure and possibly a consequence of a decreased oral intake of these two essential metals through the diet with age (17). It is possible that the concentrations in the lung could be the result of an equilibrium between metal intake by inhalation and tissue dissolution of each metal, followed by disposition throughout the organism (17).

Even though the data on individuals' occupations were incomplete, it was evident that 95% of the female subjects were homemakers in both sets. This may suggest that, among women, occupational exposure is not responsible for the sharp increases in the 1980s samples. Contrary to many reports that mention higher levels of metals among men, our results indicate similar or higher concentrations among women.

At present there is no explanation as to why women in this study would have higher exposures. It is probably the case that at home women are exposed to a great amount of not well-identified pollutants in Mexico. In Japan, there is also a report that in lung and other tissues, higher levels of metals among women may be explained by hormonal differences (40), which in some way could be part of the explanation for these variations. Further research on this topic is essential.

The only metal associated with age was lead. Lead is found in high concentrations in the blood of Mexican children, so it is possible that sources other than air explain this finding (41).

Our results call for more accurate analyses and more in-depth observations and conclusions. The focus in this research must be geared to the entire population of Mexico City, and the same attention must be given to all other urban areas in which pollution is a critical problem.

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